PROC. ENTOMOL. SOC. WASH.
87(3), 1985, pp. 545–553

IDENTIFICATION, HOSTS AND DISTRIBUTION OF *PSEUDAULACASPIS PENTAGONA* (TARGIONI-TOZZETTI) AND *P. PRUNICOLA* (MASKELL) IN VIRGINIA (HOMOPTERA: DIASPIDIDAE)

M. H. Rhoades, M. Kosztarab, and E. G. Rajotte

Department of Entomology, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061.

Abstract.—A comparison is made between host records, distribution and selected key morphological characters of *Pseudaulacaspis pentagona* and *P. prunicola* in Virginia. *P. pentagona* was recorded from 17 host genera and *P. prunicola* from five, all five of which were shared with *P. pentagona*. Both species occur throughout most of Virginia, but are more frequent in the warmer lowlands and have been recorded from only three counties in the western highlands. Significant differences were found between the species in three numerical morphological characters when using a standard *t*-test. Discriminant function analysis showed that there is a 16 percent probability of error in species determinations of *Pseudaulacaspis prunicola* collected in Virginia. Canonical discriminant analysis revealed *P. prunicola* is extremely variable in its morphology whereas *P. pentagona* is not. Two characters, number of gland spines in the third space of the pygidial margin and whether spines were forked or simple, were found to be most useful when identifying specimens.

The white peach scale, *Pseudaulacaspis pentagona* (Targioni-Tozzetti), is a common insect pest of a wide range of ornamental plants and fruit trees. Although it can occur in any county of Virginia, at present it is a serious pest only from the Piedmont eastward. What has been known up until now in the U.S. as *P. pentagona* was recently found to consistof two cryptic species, *P. pentagona* (PE) and *P. prunicola* (Maskell) (PR), both of which are cosmopolitan and polyphagous (Davidson et al., 1983). In their summary, they state that PE tends to be more southern in distribution and occurs commonly on *Prunus, Morus, Callicarpa, Diospyros* and *Melia,* whereas PR tends to occur farther north and often occurs on *Prunus, Ligustrum* and *Syringa.* They found that ranges of the two overlap in the U.S. and that there are exceptions to the trends mentioned above.

Five morphological characters were used by Davidson et al. (1983) to distinguish PE from PR: number of gland spines in the third space on the pygidial margin; presence of forked versus unforked spines in the second, third, or fourth spaces; number of perivulvar pores; number of large macroducts; and number of small macroducts on the metathorax and first abdominal segment. Significant differences between the two species were found for all four of the numerical characters when they were compared using a standard *t*-test.

On a practical basis, identification laboratories usually only receive short series of specimens that are often poorly mounted. In the case of scales, many characters are not visible in poor mounts, and poorly visible in all but the best mounts. When identifications are made, they are made with a certain probability of error due to the suboptimal condition of the specimens, or misinterpretation by the taxonomist. Another source of error is the inappropriateness of the literature used as the basis of the identification, e.g. use of a key prepared for European species to identify specimens from the United States. Many keys and descriptions of insect species may be based on specimens from either certain geographical areas or from world populations. These descriptions can be misleading for local specimens for two reasons: 1) Many morphological characters are variable even within a single species. If these characters are correlated with some other variable such as geographic distribution or host preference, then comparing locally collected specimens with those from another location may involve extreme ends of naturally occurring morphological distributions; 2) If descriptions are based on population samples from many different parts of the world, the morphological description would tend to reflect the center of any distribution. If the locally collected specimens represent extremes in the distribution of any morphological character, there is a possibility that they will be misidentified.

The purpose of this paper is to use the criteria of Davidson et al. (1983) to separate specimens of PR and PE from Virginia, give the current distribution and host records of each species, describe the shortcomings of the criteria when working on local populations, and describe the error associated with identifications using this method.

Materials and Methods

Information for this study was taken from the 378 Virginia specimens of slide-mounted adult female *Pseudaulacaspis* in the VPI&SU collection. Four morphological characters were used for comparisons among Virginia specimens: number of gland spines in the third space (spines), presence or absence of forked spines (forks), number of large dorsal macroducts (ducts), and total number of perivulvar pores (pores). The number of small macroducts was not considered in this study because they are much more difficult to see than large macroducts and consequently would not be of much use to inexperienced persons trying to key out a specimen of *Pseudaulacaspis*.

The two characters we used were number of gland spines in the third space and whether spines were forked or simple to assign specimens to either PE or PR. Then, for each species, we found the mean, range and variance for spines, ducts, and pores. We chose to record only the presence or absence of at least one forked spine as the fourth character (non-numeric) and did not consider the number of spines which were forked or the degree of forking because this would be difficult to quantify.

To compare values for spines, pores and ducts of our Virginia material with values obtained by Davidson et al. (1983) we used the same statistical analysis they did, a standard *t*-test to determine significant differences between the two species.

Because specimens are sometimes encountered for which either pores or ducts cannot be counted, or spines are broken off, we also calculated Spearman's cor-

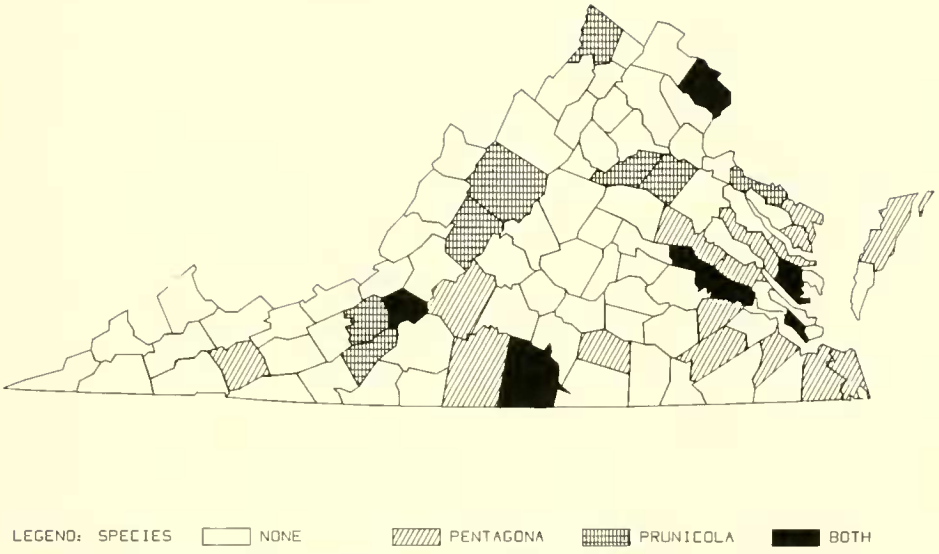

Fig. 1. Known distribution of *Pseudaulacaspis* species in Virginia.

relation coefficient within each species for each combination of characters to find if any correlations existed.

In addition, variation of characters with different hosts was explored using a one-way analysis of variance. Samples of PE (ranging from 10 to 26 specimens each) collected from *Catalpa, Morus, Prunus, Salix,* and *Syringa* were compared. Each sample represented several separate collections from each host. Not enough specimens of PR were available from different hosts to conduct a similar comparison for it.

To describe the error in classification due to using the criteria of Davidson et al. (1983) on the Virginia material, we employed a discriminant function analysis and canonical discriminant analysis. Whereas the *t*-test analysis compared spines, pores and ducts between species one at a time, the discriminant analyses compared those three variables plus a fourth variable (forks) simultaneously. Information from these analyses allowed us to estimate misclassification probabilities and the importance of each morphological character in making species determinations.

The discriminant function analysis computes a distance function that can be used to classify two or more groups on the basis of one or more numerical variables. Each observation is placed in the class from which it has the smallest generalized squared distance (Harris, 1975). The canonical discriminant analysis is a dimension reduction technique. Canonical variables (linear combinations of quantitative variables) are derived that summarize between-class variation by creating the linear combination of variables that has the highest possible multiple correlation with the groups. The frequency of species is then plotted along the canonical axis to show the degree of overlap between the species (Harris, 1975).

Results

Determination of species.—Of 81 collections (comprising 378 specimens) of *Pseudaulacaspis* from Virginia, 44 were identified as PE, 34 as PR, and 3 as

Table 1. Recorded hosts of *Pseudaulacaspis* in Virginia.

Plant Family	Genus	Number of Collections	
		pentagona	*prunicola*
Bignoniaceae	*Catalpa*	5	1
Buxaceae	*Buxus*	2	
Brassicaceae	*Iberis*	4	
Ericaceae	*Rhododendron*	1	
Juglandaceae	*Carya*	1	
	Juglans	1	
Fabaceae	*Glycine*	1	
Lythraceae	*Lagerstroemia*	1	
Magnoliaceae	*Magnolia*	1	
Moraceae	*Broussonetia*	2	
	Morus	4	
Oleaceae	*Fraxinus*	1	
	Ligustrum	2	5
	Osmanthus	2	
	Syringa	5	4
Rosaceae	*Prunus*	5	23
Salicaceae	*Salix*	6	1
	Total =	44	34

intermediate. Specimens classified as intermediate either had one side of the pygidium resembling PE and the other side PR, or the gland spines were truly a blend on both sides, i.e. two spines were present but one was forked, or one spine was present but it was not forked. Ten of the collections were initially called intermediate, but a re-examination of specimens left only three collections in this category. Those which were moved out of the intermediate group usually had one or more specimens which were hard to classify, but had the majority of specimens fitting PR. Those which were left in the intermediate group had the majority of specimens with a blend of characters or an equal number of specimens resembling each species.

The earliest collection of PR in Virginia was from Richmond in 1937 on *Li-*

Table 2. Comparison between a world population sample and a Virginia population sample for three morphological characters of *Pseudaulacaspis pentagona* and *P. prunicola*.

Character	Species	Mean		±Stand. Error		Range		Sample Size		*t*-test Value[2]	
		Va	World[1]	Va	World	Va	World	Va.	World	Va.	World
No. of large macroducts	*pent.*	52.74	67.66	0.84	2.28	28–77	40–106	123	50	5.60	3.57
	prun.	46.41	57.64	0.75	1.59	24–78	38–86	158	47		
No. of perivulvar pores	*pent.*	65.88	76.04	0.91	2.21	43–104	51–124	141	65	2.83	3.92
	prun.	62.71	65.39	0.68	1.60	37–85	35–99	162	67		
No. of gland spines in 3rd space	*pent.*	1.06	1.05	0.01	0.03	1.0–2.0	—	194	65	22.60	12.56
	prun.	1.92	2.07	0.04	0.08	1.0–3.0	—	181	58		

[1] Values for the world population sample are from Davidson et al., 1983.
[2] All values significant at $\alpha = .01$ or less.

Table 3. Correlation between no. of gland spines in third space, no. of perivulvar pores and no. of large macroducts for all samples of *Pseudaulacaspis pentagona* and *P. prunicola* collected in Virginia.

Characters Compared*	*P pentagona*		*P prunicola*	
	Spearman Correlation Coefficient	Probability	Spearman Correlation Coefficient	Probability
Spines/Pores	0.0279	0.7435	−0.0110	0.8914
Spines/Ducts	−0.1360	0.1353	0.1712	0.0350
Pores/Ducts	0.6365	0.0001	0.0843	0.3083

* In each case N = 100.

gustrum. The earliest for PE was from Roanoke in 1940 on *Catalpa*. For the intermediate group, the oldest specimen was from Fairfax in 1968 on *Prunus*.

Distribution.—Both PE and PR occur throughout Virginia. Current records indicate PE in 23 counties and PR in 15 (see Fig. 1). Although *Pseudaulacaspis* has been collected from only three counties in the mountainous western region of Virginia, this probably reflects its lack of pest status there rather than its lack of occurrence. The three collections of intermediates were from Fairfax, Fredericksburg, and Henry County.

Hosts.—In Virginia, PE has a much wider range of host plants than PR, the former attacking 17 genera in 12 different plant families, whereas the latter occurs on five plant genera in only four families (see Table 1). All five plant genera that serve as hosts for PR are also known as hosts for PE. Common hosts of PE in Virginia are *Catalpa, Morus, Prunus, Salix,* and *Syringa*. Sixty-eight percent of all PR collections were from *Prunus*.

Character comparison.—A comparison between Virginia specimens and those in the world sample for three morphological characters is given in Table 2. The mean number of ducts for PE from Virginia was 52.74, for PR 46.41. The difference was highly significant. Both values are well below the means derived from the world population sample. The range of values in number of ducts for Virginia specimens of PE overlapped completely with those of PR. The mean number of

Table 4. Influence of host on two morphological characters of *Pseudaulacaspis pentagona*. Comparison of mean no. of large macroducts and perivulvar pores using a one-way analysis of variance.

Host Genus	Morphological Character	Least Squares Mean	±Standard Error
Catalpa	ducts	50.85	2.35
n = 13	pores	69.23	2.76
Morus	ducts	50.45	2.55
n = 11	pores	64.55	3.00
Prunus	ducts	49.90	2.68
n = 10	pores	65.60	3.15
Salix	ducts	52.50	1.66
n = 26	pores	65.35	1.95
Syringa	ducts	59.50*	2.68
n = 10	pores	72.50	3.15

* Significantly different at the 5% level.

Table 5. Results of using discriminant function analysis based on four morphological characters to identify specimens of *Pseudaulacaspis* in Virginia.

From Species		Number of Observations and Percentages Classified into Species		
		pentagona	*prunicola*	Total
pent.	no.	115	0	115
	%	100.00	0.00	100.00
prun.	no.	23	118	141
	%	16.31	83.69	100.00
Total	no.	138	118	256*
	%	53.91	46.09	100.00

* Only specimens with values for all four characters were used in this analysis.

perivulvar pores was 65.88 for Virginia PE and 62.71 for PR. As in the case of ducts, the difference was highly significant. Values for the world population sample were higher than for the Virginia sample for both species, and there was a greater separation of means. The range of values for pores in the Virginia sample showed a great deal of overlap between species.

The mean number of gland spines in the third space for PE was 1.06, for PR 1.92. The difference was highly significant for this character also (Table 2). Values for the world population sample were almost identical for PE but substantially higher for PR.

The range in number of pores and ducts within one population was found for each species by choosing one collection of each from which we had mounted a large number of specimens. Values were: for PE (n = 20, host = *Salix*)—pores 45–84, ducts 44–70 and for PR (n = 21, host = *Prunus*)—pores 49–80, ducts 36–60. Although ranges were narrower for individual populations than for the entire Virginia sample, there was still considerable variation present.

Correlation among characters.—A highly significant correlation was found in PE between number of pores and number of ducts (Table 3). There were no other strong correlations.

Variation among individuals from different hosts.—It is apparent that the specimens collected from *Syringa* (Table 4) possessed the highest number of both pores and ducts. Mean number of ducts ranged from 49.9 for PE on *Prunus* to 59.5 for PE on *Syringa*. Number of ducts for specimens on *Syringa* were significantly different from all others. Mean number of pores ranged from a low of 64.5 for specimens on *Morus* to a high of 72.5 for those on *Syringa*. There was no significant difference among means for pores.

Table 6. Canonical scores or weights for four morphological variables of *Pseudaulacaspis* specimens from Virginia.

Character	Within Class Canonical Structure	Normalized Canonical Coefficients	Raw Canonical Coefficients
Forks	0.7486	0.9369	1.8984
Spines	−0.7417	−1.0026	−1.6979
Ducts	0.2100	0.3073	0.0306
Pores	0.1180	−0.0544	−0.0056

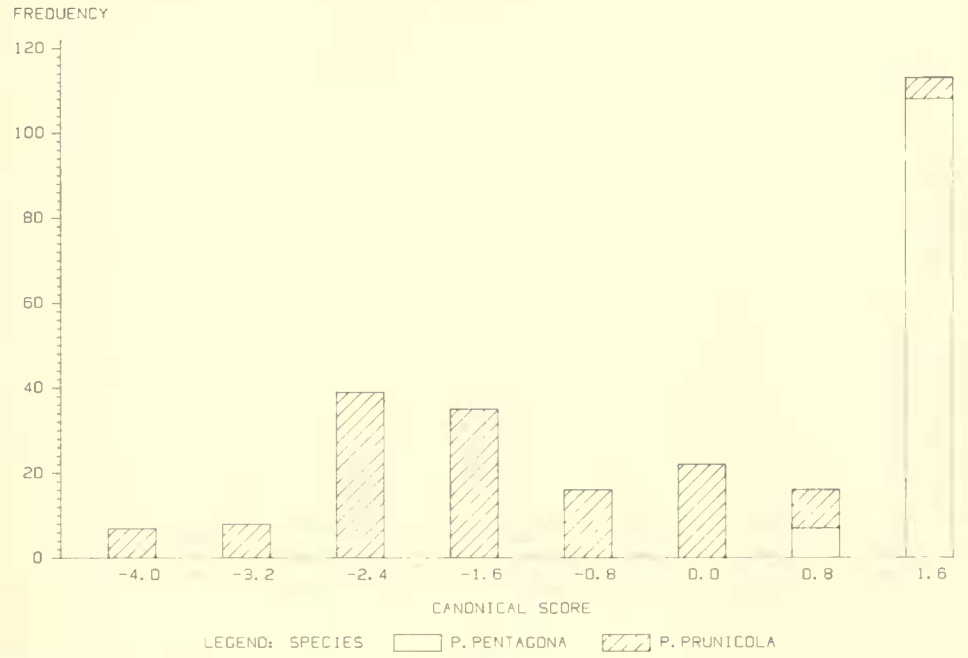

Fig. 2. Frequency of each species along canonical axis.

Discriminant function analysis and canonical discriminant analysis.—The discriminant analysis revealed that when using all four characters—forks, spines, ducts and pores—there were no errors in species determinations of PE, but 16 percent of PR were wrongly identified (Table 5).

Also, as indicated by the canonical discriminant analysis, each of the four characters was of different importance in identifying the specimens. The relative importance or canonical weight of each character is displayed in Table 6. In all three cases, the within class canonical structure, the normalized canonical coefficients and the raw canonical coefficients, the same pattern is seen. The canonical weights are high and inversely related for forks and spines and low for ducts and pores. Obviously, forks and spines contribute the most to discriminating between species and ducts and pores do not contribute much at all. The first canonical variate is pictured in Fig. 2. PR has a wider distribution over the canonical axis representing its extremely variable morphology. PE has a much tighter distribution indicating less morphological variability among specimens. At the zero point on the axis PR overlaps into the PE region and therefore these specimens may be misidentified as PE. PE does not overlap at all into the PR region indicating that none of PE would be misclassified.

Summary

Our results support the conclusion of Davidson et al. (1983) that *P. pentagona* and *P. prunicola* are two distinct species. However, their species concept, derived from samples from around the world, presents some problems for a small geographical area (Virginia) where both species have been present for at least forty years. The mean number of large macroducts and perivulvar pores for the two

species in Virginia are quite different from those for both species in the world sample. This indicates that values may have to be determined for a particular region of the country before they can be used as an aid in distinguishing populations of the two species. A review of specimens from Pennsylvania or New York, as well as Florida or South Carolina should reveal whether numbers of pores and ducts vary significantly from one region to another. Furthermore, we found specimens with characters intermediate between the two species which were difficult to classify.

For the average species determination, when only two or three specimens are examined, counting the number of ducts and pores may not be useful because of the large variation in their values even within one population. To distinguish between the two species, we suggest relying on the number of gland spines in the third space of the pygidial margin and whether the spines are forked or not. When an intermediate specimen is encountered using these two characters, it will be necessary to examine several more specimens from the same population. Our results indicate that the number of large macroducts will be more reliable to use in distinguishing differences than the number of perivulvar pores because there was a greater difference between means for the two species in number of ducts than number of pores, and greater differences were found among means for ducts than pores when specimens of *P. pentagona* from different hosts were compared.

According to our discriminant analyses, there is a 16 percent probability of error in species determinations of Virginia collected PR based on the criteria of Davidson et al. (1983). This may be an acceptable error rate depending on the use to which the determinations will be put. If high value decisions will be based on these determinations the 16 percent probability of error may be translated into a substantial monetary loss. For instance, if PE is a highly destructive species and PR is not, then misidentification may cause expensive and unnecessary pest management costs if the species truly is not PE but is identified as such, or misidentification can cause preventable destruction if the species truly is PE but is identified as PR. The discriminant analysis can help in this situation also. The prior probabilities can be adjusted to reflect the consequences of making erroneous decisions and therefore bias the analysis based on the "cost" of the erroneous decision.

It appears that *P. pentagona* is somewhat more firmly established than *P. prunicola* in Virginia because it was collected more often and it occurs in more counties. The exact pest status of each species requires further investigation.

Data from previous works on *P. pentagona* in the U.S. must be re-evaluated in light of the fact that both it and *P. prunicola* are present in the U.S. If voucher specimens were kept, they should be re-examined. Although there are records of *P. pentagona* from as far north as Indiana and records of *P. prunicola* from as far south as Florida, we cannot delineate the range of either species from present records because we do not know whether these specimens came from established populations or not. The fact that *P. prunicola* has been collected in Florida and probably in Sri Lanka (latter unconfirmed, see Maskell, 1898) seems to indicate it is not restricted to more northerly regions than *P. pentagona*. Conversely, records of *P. pentagona* from New York and Indiana suggest the possibility that it ranges as far north as *P. prunicola*.

Acknowledgments

We thank E. E. Tan and E. P. Smith, Department of Statistics, for their consulting services; the above plus D. G. Pfeiffer for reviewing the manuscript; also L. Claxton and D. Martin for technical assistance, all of Virginia Polytechnic Institute & State University. Personal consultation with D. R. Miller, Systematic Entomology Laboratory, Agricultural Research Service, Beltsville, Maryland, concerning certain aspects of the study of *P. pentagona* and *P. prunicola* from around the world is also gratefully acknowledged. A National Science Foundation grant (BSR-8415644) provided partial funding for this research.

Literature Cited

Davidson, J. A., D. R. Miller, and S. Nakahara. 1983. The white peach scale, *Pseudaulacaspis pentagona* (Targioni-Tozzetti) (Homoptera:Diaspididae): Evidence that current concepts include two species. Proc. Entomol. Soc. Wash. 85: 753–761.

Harris, R. J. 1975. A Primer of Multivariate Statistics. Academic Press, New York. 332 pp.

Maskell, W. M. 1898(1897). Art. XXVI. Further coccid notes: With description of new species, and discussion of points of interest. Trans. Proc. N.Z. Inst. 30: 219–252.